



MI SBD Specifications

Chandra Bhat,

A. Marchionni, I. Kourbanis, D. Capista,

October 27, 2004

DRAFT
Revision 4

Abstract:

In this report we present the MI SBD specifications and requirements for the Run II, NuMI and SY120 operation of the MI from now till ~2010 for longitudinal emittance measurements. Various modes of operation of the MI during this time are outlined in two tables with expected properties of the beam (cycle type, rep. rate, beam intensities, bunch length, bunch structure and energy range of the MI etc.). The SBD modes presently being used are also shown. Some typical cases of wall current monitor data and schematic view of various MI cycles of interests are displayed. We also give algorithm to be used in the emittance calculations.



What are MISBD mode files?

Mode file is an input parameter list for MISBD system which uniquely defines a particular mode of operation of MI.

1.	Title	2A&9A pbar Emittance Measurement			
2.	Mode Number	17		16.	# of displayed buckets 84
3.	Injection Frequency(kHz)	89.815		17.	TV display control 1
4.	Harmonic Number	588		18.	1 st call -1
5.	Transition Energy	20.488		19.	Injection Momentum 8.8889
6.	TclkReset	2A		20.	Bunches /batch 21
7.	TclkTrigger	9A		21.	Spare 1
8.	#of Batches	4		22.	Spare 2
9.	# of Acquisitions (Range 1-24)	3	} ←	23.	Spare 3
10.	Starting Time (sec)	4.3		24.	Spare 4
11.	Delta t	0.0			
12.	Giga Samples/sec	4			
13.	Gain	0.05			
14.	Starting Sample	055			
15.	First Displayed Bucket	0			

This combination tells the SBD system to take traces 1+3 times. First time the trace will be taken at 4.3sec after 2A and next three times traces will be taken at I:SBDTIM[1],I:SBDTIM[2] and I:SBDTIM[3] set by user by this mode table.



SBD Modes: Collider Operation



Operational

Description of the Cycle	Beam (cycl. Time)	Bunch Type	Mode #	Energy Range (GeV)	Intensity Range	Expected Min.rms-width (nsec)	Applications **
Pbar Stacking \$29 +1F, # of Bunches = 84	P (1.47s)	53MHz	4	8-120	1-10 ×10 ¹²	≈ 0.25 (@ tran.)	Stacking efficiency SDA
Protons to Tevatron \$2B+15, # of Bunches = 5-7	p (3.5s)	53MHz	19	8-150	0.2-0.6 ×10 ¹²	≈ 0.25 (@ tran.)	Ppbar Luminosity SDA
AR Pbars to Tevatron \$2A+9A, # of Bunches = 4	Pbars (8 s)	2.5MHz @ inj. 53MHz @Ext.	17	8-150	5-50×10 ¹⁰	≈0.25 (@ tran.)	Ppbar Luminosity SDA
RR Pbars to Tevatron \$2A+E4, # of Bunches = 4	Pbars (8 s)	2.5MHz @ inj. 53MHz @Ext.	18	8-150	5-100×10 ¹⁰	≈ 0.25 (@ tran.)	Ppbar Luminosity SDA
AR Pbars to RR \$2D+E0, # of Bunches = 4	Pbars (5 s)	2.5MHz	16	8	5-100×10 ¹⁰	≈ 12	RR-pbar stacking efficiency, SDA
RR Pbars to MI to RR \$2D+E4, # of Bunches=4	Pbars (5 s)	2.5MHz	??	8	5×10 ¹⁰	≈ 12	Round trip efficiency SDA

Study/Development

RR Pbars to Tev., 2.5MHz Accel.* \$20+E4, # of Bunches = 4	Pbars (13 s)	2.5MHz @ inj. 53MHz @Ext.	15	8-150	4-100×10 ¹⁰	≈ 2	Ppbar Luminosity SDA
Proton, 2.5MHz Accel. \$20+1C, # of Bunches = 4	p (13 s)	2.5MHz @ inj. 53MHz @Ext.	14	8-150	5-100×10 ¹⁰	≈ 2	Acceleration Tuning
Protons to RR \$2D+1C, # of Bunches = 4	p (5 s)	2.5MHz @ inj.	12	8	5-100×10 ¹⁰	≈ 12	RR Tuning

* The cycle combinations will be changed from \$20+XXX to \$2A+ XXX once it is made operational

** The expected "Min rms width" will not be used in the final applications. But the Min rms width will be used for establishing the SBD specifications

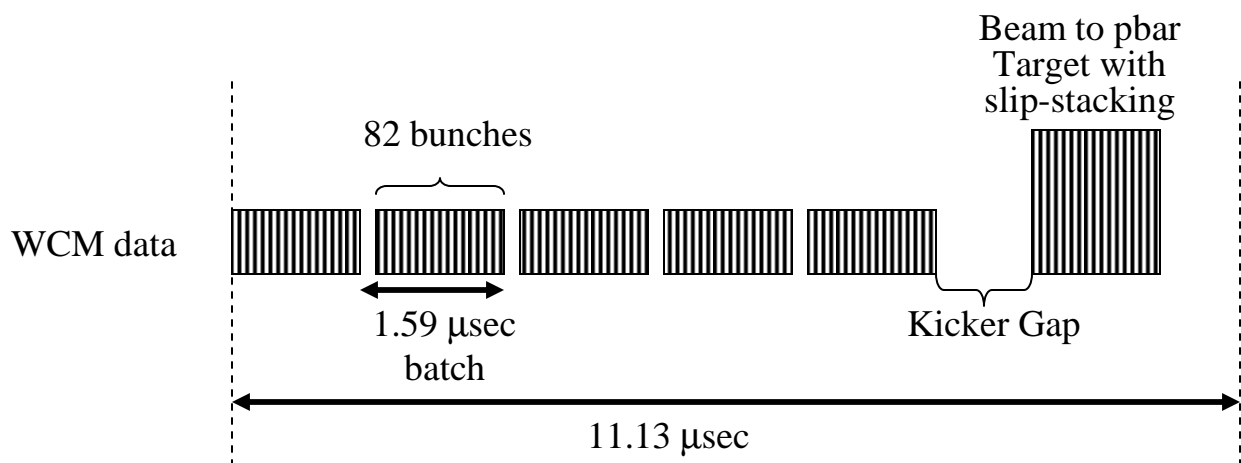


SBD Modes: Fixed Target Experiments

Description of the Cycle	Beam	Bunch Type	Mode #	Energy Range (GeV)	Intensity Range	Expected Min.rms-width (nsec)	Applications *
NuMI \$23 +19, # of Bunches = 82×6	P (1.9s)	53MHz	??	8-120	$1-4 \times 10^{13}$	≈ 0.25 (@ tran.)	Stacking efficiency
Pbar Stacking +NuMI (Mixed mode) \$23 +19, # of Bunches = 82×6	p (~2s)	53MHz	??	8-120	$1-5 (??) \times 10^{13}$	≈ 0.25 (@ tran.)	Stacking efficiency and quality of the beam on NuMI target
Pbar Stacking + SY (Mixed Mode) \$21 +13, # of Bunches = 82×6	p (~3s)	53MHz	??	8-120	$1-10 \times 10^{12}$	≈ 0.25 (@ tran.)	Stacking efficiency

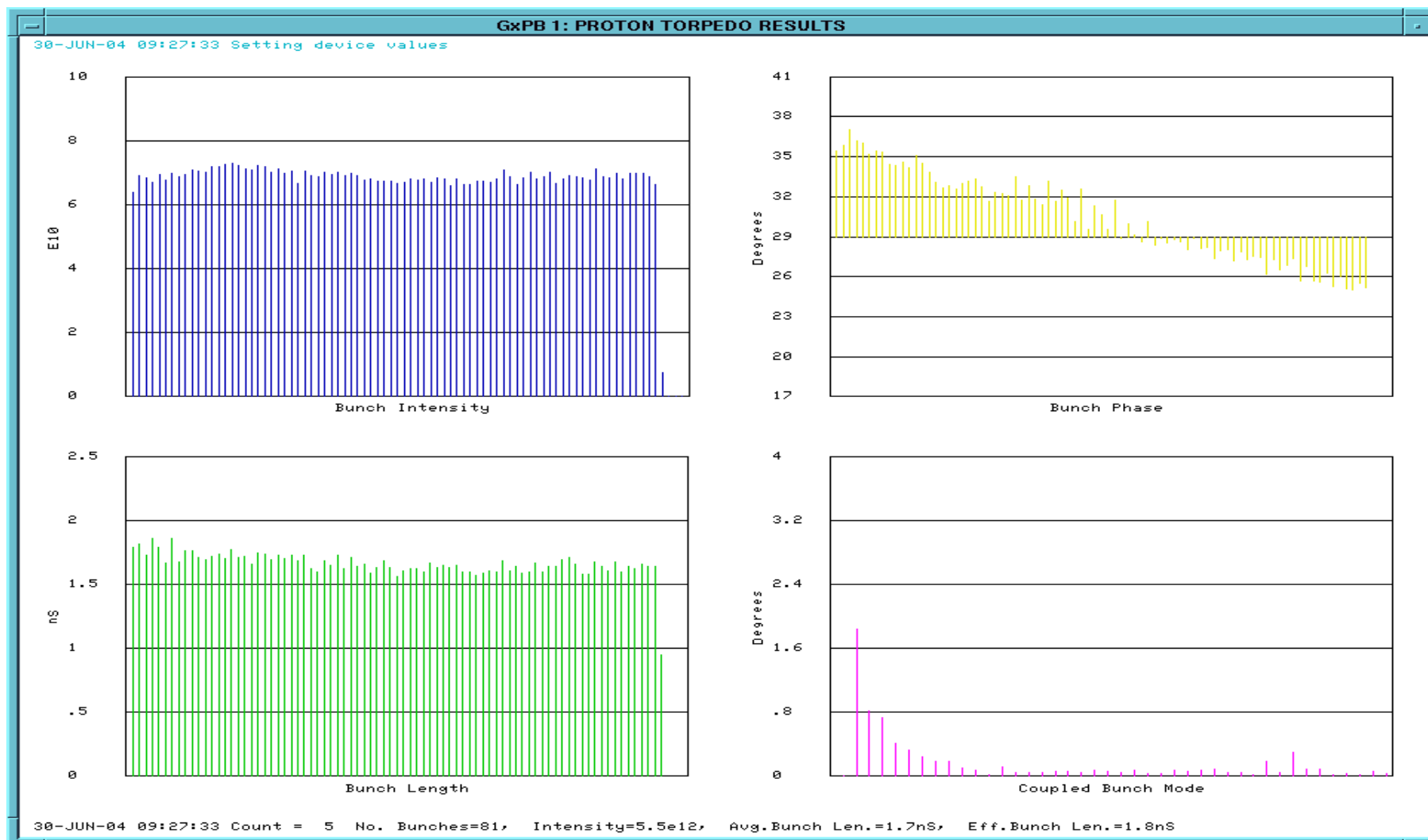
* The expected “Min rms width” will not be used in the final applications. But the Min rms width will be used for establishing the SBD specifications

Schematic View of the Bunch Traces during Mixed Mode Operation:



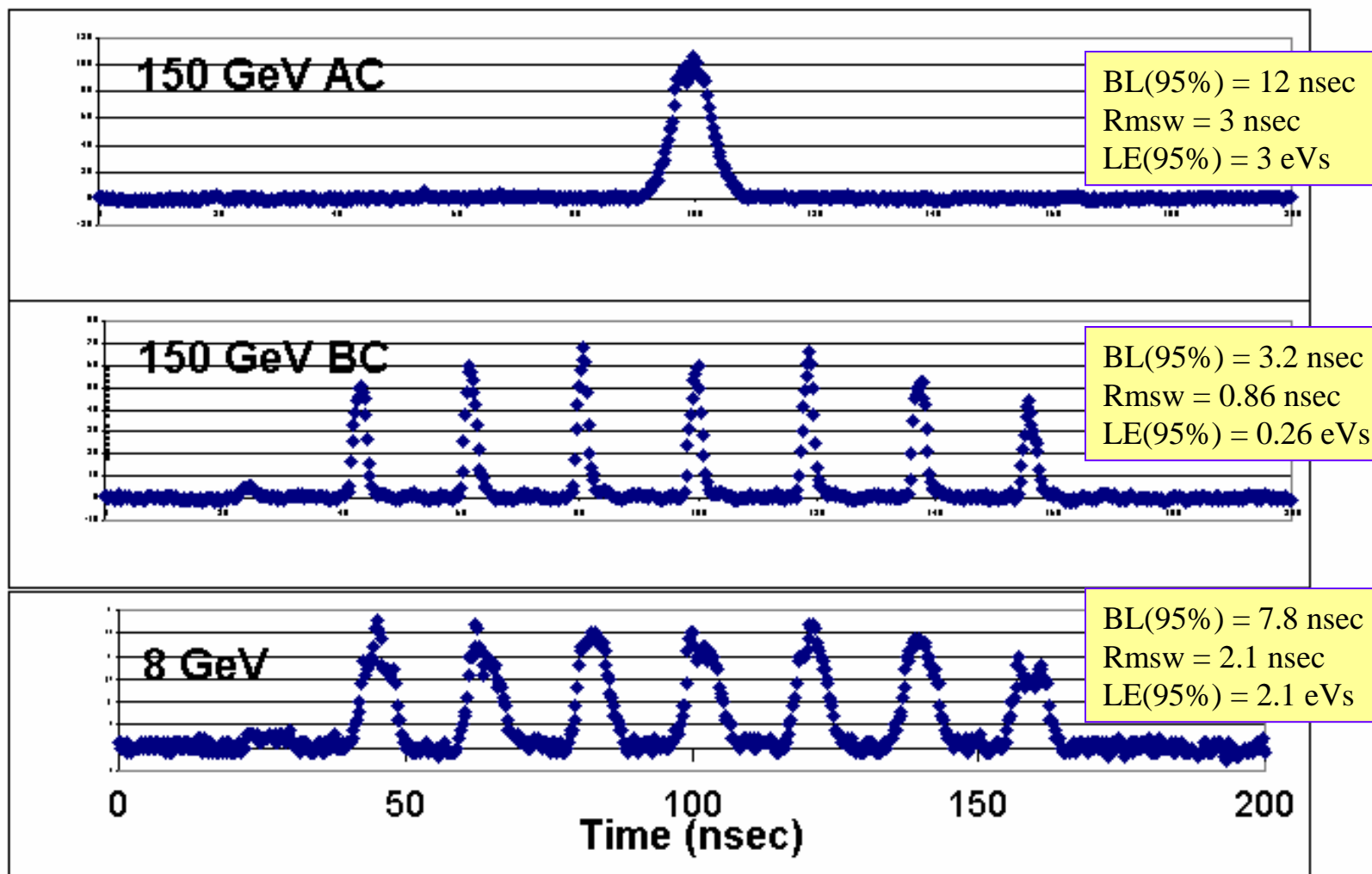


Sample of Proton torpedo display in the pbar beam-line



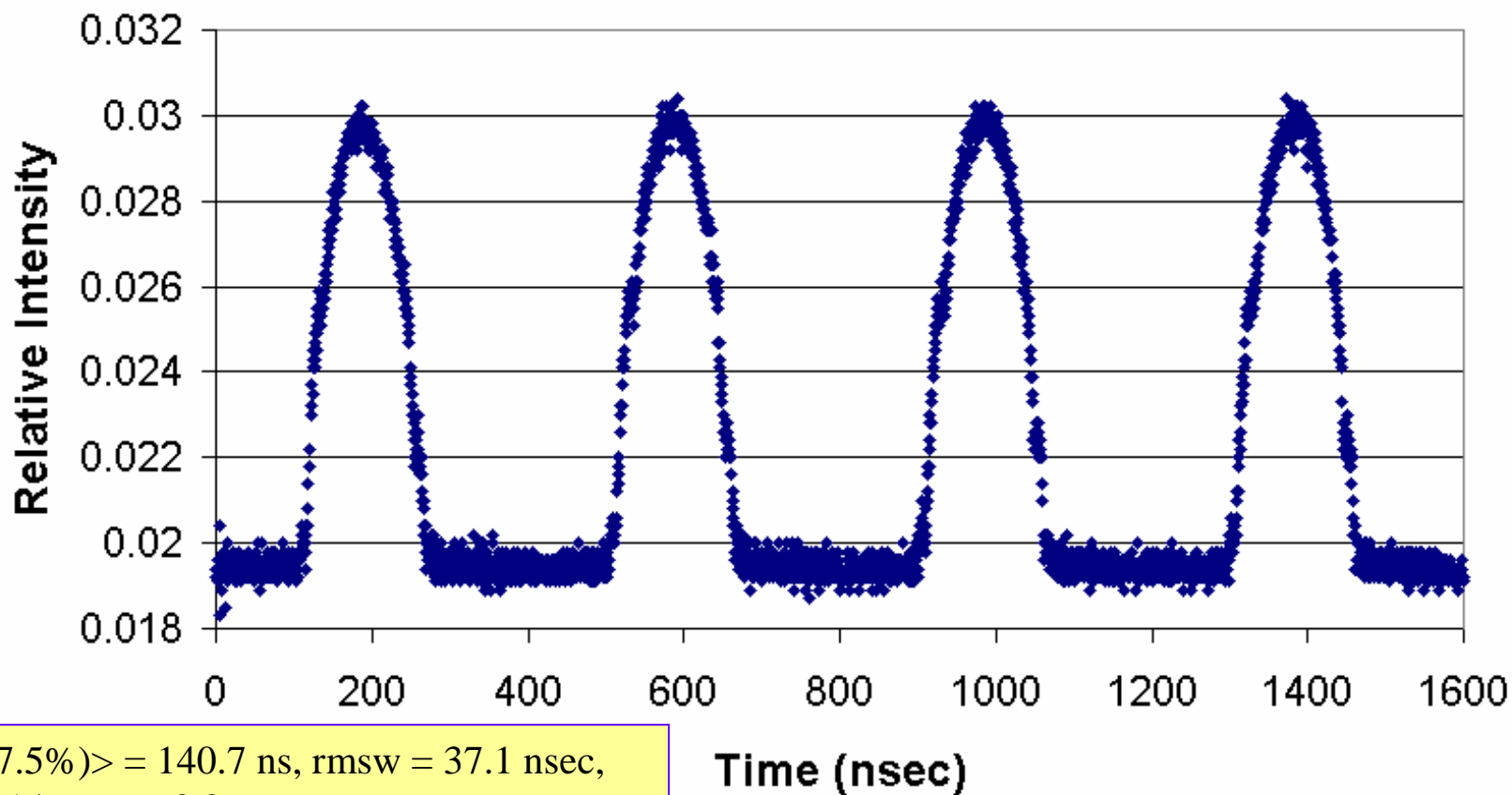


Sample of Proton bunches to Tevatron: 53MHz Bunches





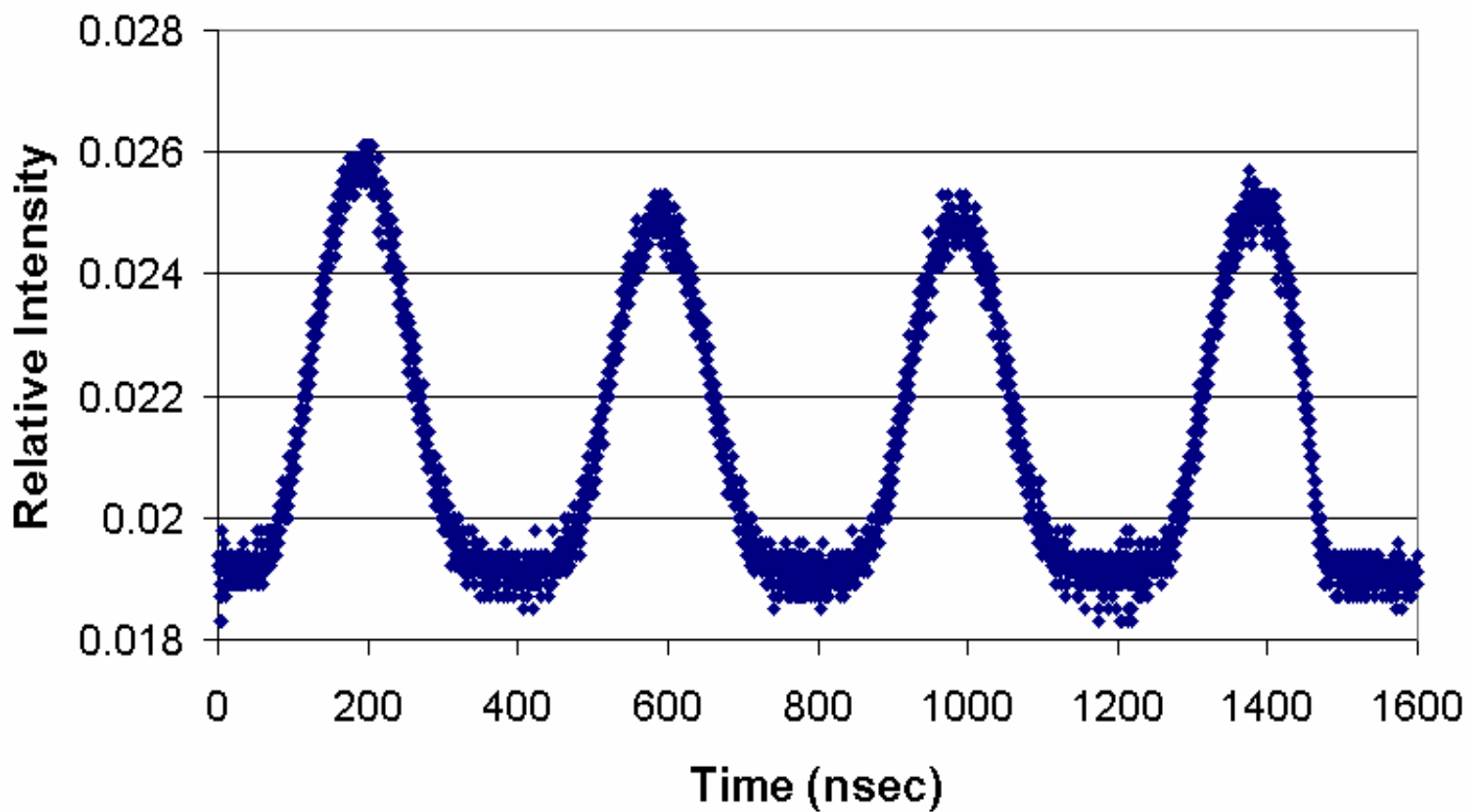
2.5MHz pbar Bunches at 8 GeV AR to MI



$\langle \text{BL} (97.5\%) \rangle = 140.7 \text{ ns}$, $\text{rmsw} = 37.1 \text{ nsec}$,
 $\text{BL}(95\%)/\text{rmsw} = 3.8$
 $\langle \text{LE}(95\%) \rangle = 0.66 \text{ eVs}$
Meas. At MI $\langle \text{LE} (\text{full}) \rangle = 0.83 \text{ eVs (fit)}$
Meas. At AR $\langle \text{LE} (\text{full}) \rangle = 0.82 \text{ eVs (fit)}$



2.5MHz pbar Bunches at 8 GeV RR to MI



$\langle \text{BL} (97.5\%) \rangle = 214.2 \text{ ns}$, $\langle \text{rmsw} \rangle = 51.3 \text{ nsec}$,
 $\text{BL}(95\%)/\text{rmsw} = 4.18$
 $\langle \text{LE}(95\%) \rangle = 2 \text{ eVs}$

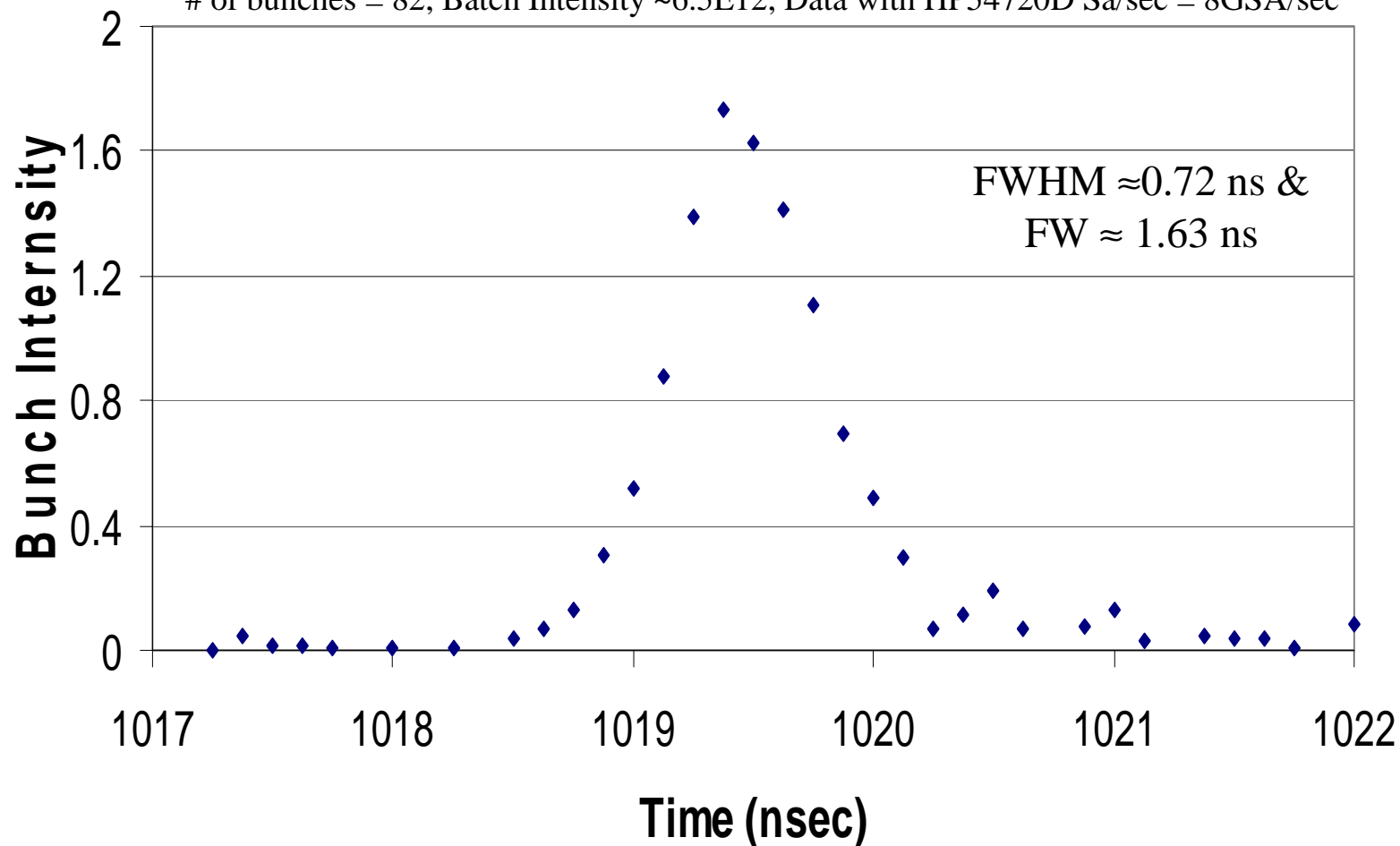


Typical case of a bunch at 120 GeV

Beam with slip stacking after bunch rotation

Data from Kiyomi Seiya (October, 6 2004)

of bunches = 82, Batch Intensity $\sim 6.5E12$, Data with HP54720D Sa/sec = 8GSA/sec





Formula for Longitudinal Emittance Calculations

Longitudinal Emittance in eVs

$$\varepsilon_l = 121.733 \sqrt{\frac{\gamma V_{rf} (MV)}{|\eta| h^3}} \int_0^Q \sqrt{\cos(x) - \cos(Q)} dx$$

where γ is the ratio between beam energy to proton rest energy and Q is half bunch length in radian

$$Q = \pi (\text{Bunch Length}(ns) / \tau)$$
$$\tau = \frac{\text{Revolution Period}(ns)}{h}$$

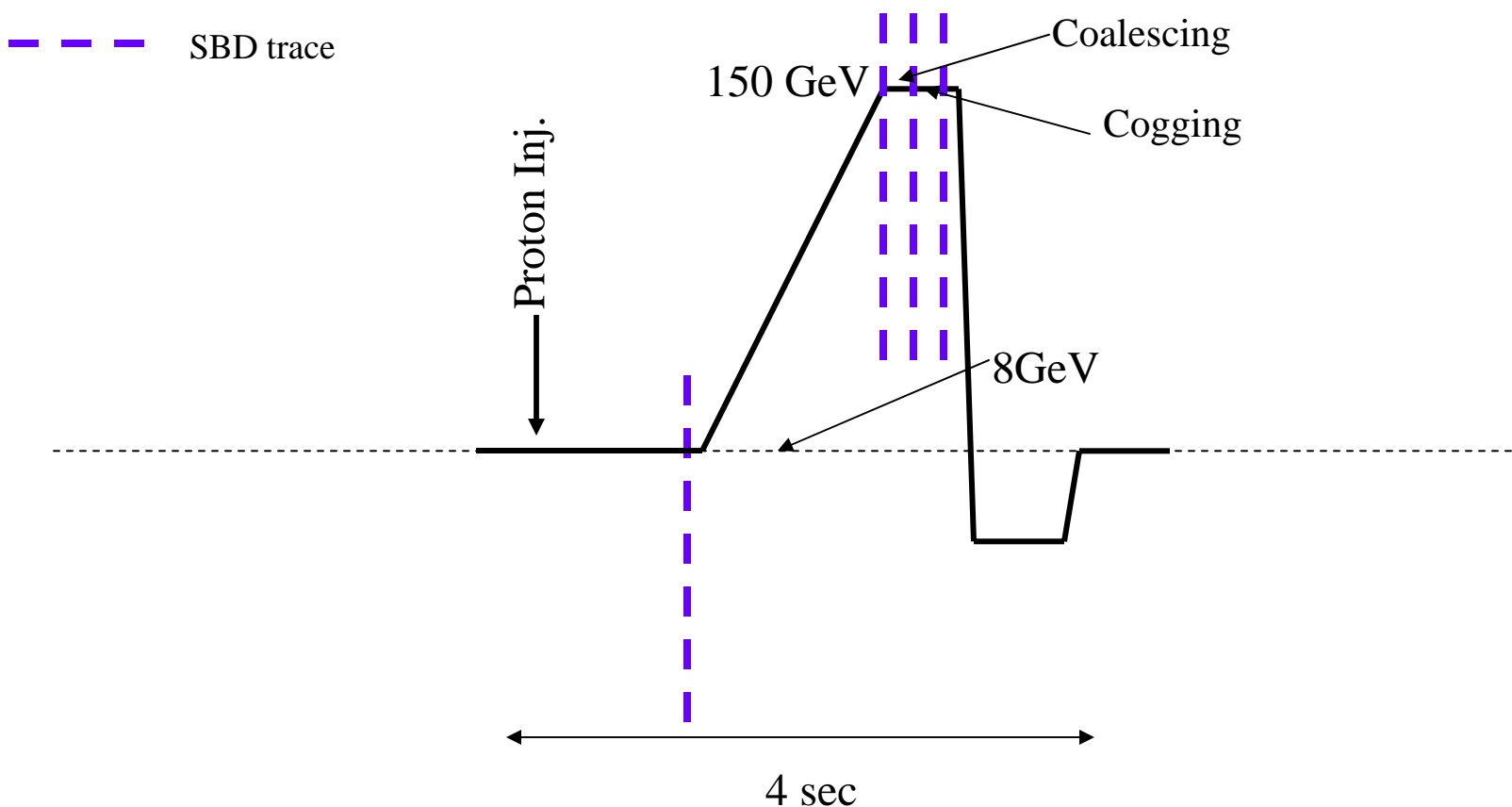
Bunch Length = $C \langle RMSW \rangle$; $C=4$, a better value will be set later

$$\frac{dp}{p} (\%) = \pm 2.604 \sqrt{\frac{V_{rf} (MV)}{|\eta| h \beta^2 \gamma}} \sin\left(\frac{Q}{2}\right)$$

$h = 28$ for 2.5MHz rf bunches and $h=588$ for 53MHz bunches

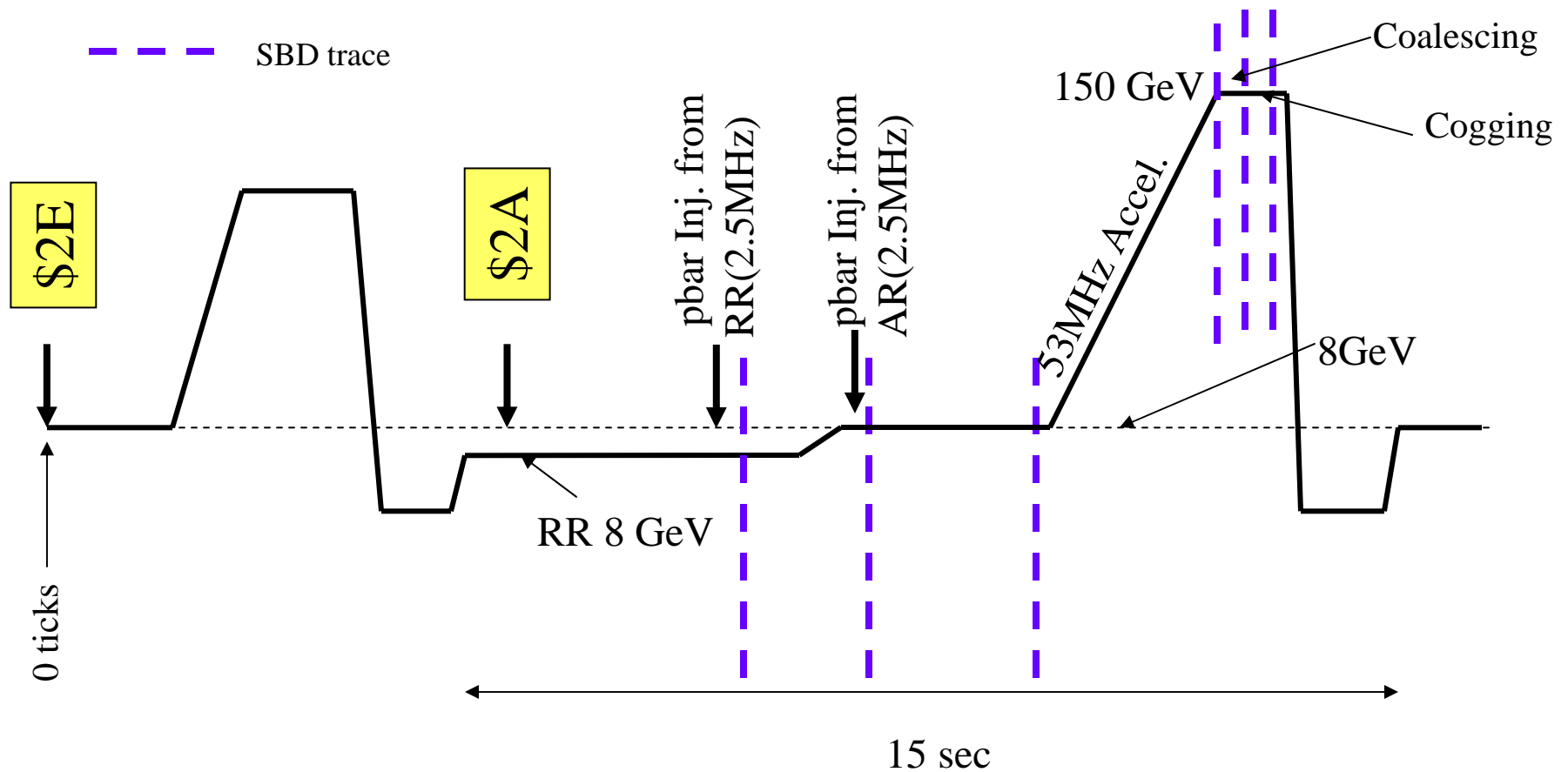


MI cycle: Booster Protons to Tevatron, 53 MHz Acceleration





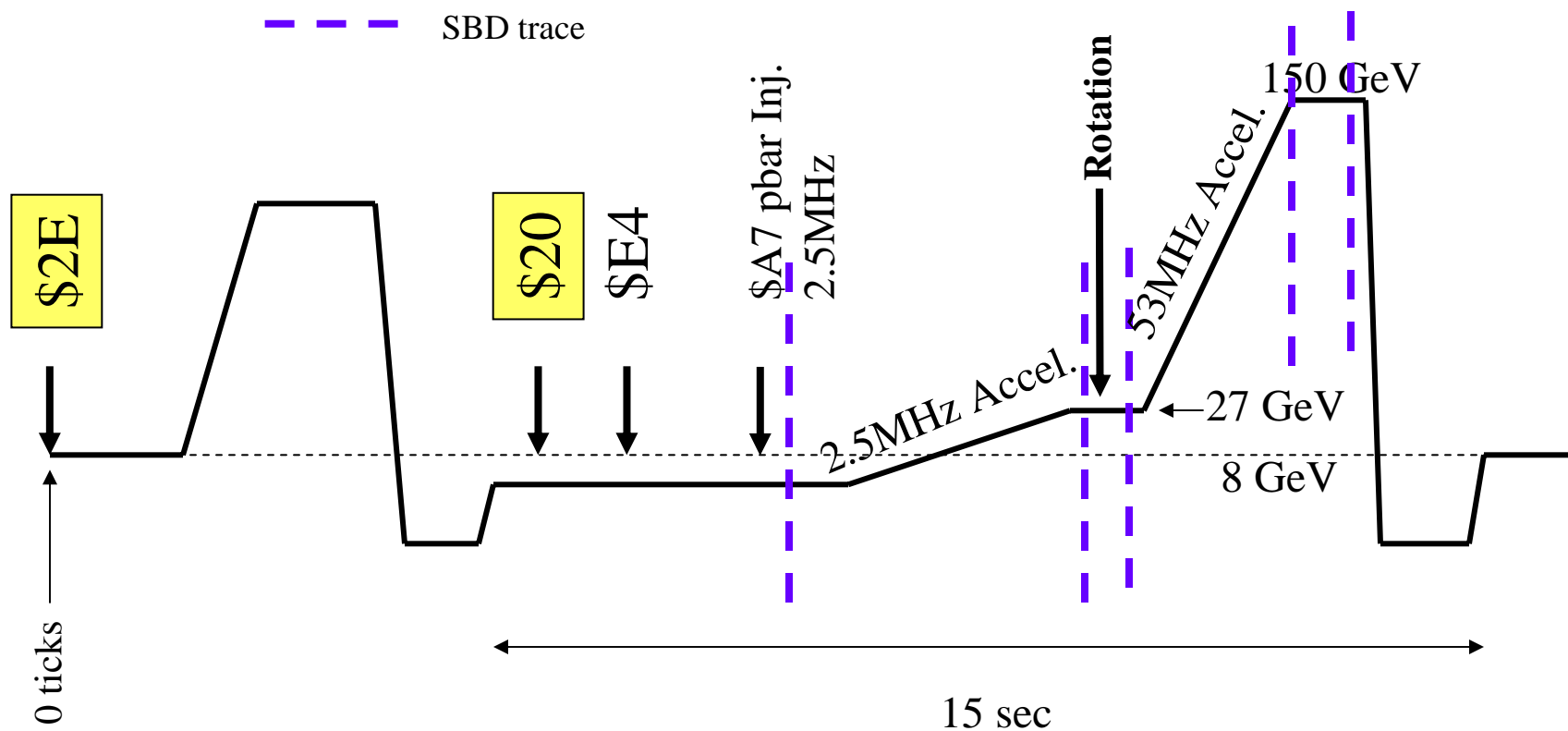
MI cycle: AR/RR Pbar to Tevatron, 2.5MHz pbar injection and 53MHz Acceleration



--- Need SBD at these points in the cycle



MI cycle: RR Pbar Acceleration from 8-27 GeV with 2.5MHz +27-150 GeV with 53MHz systems

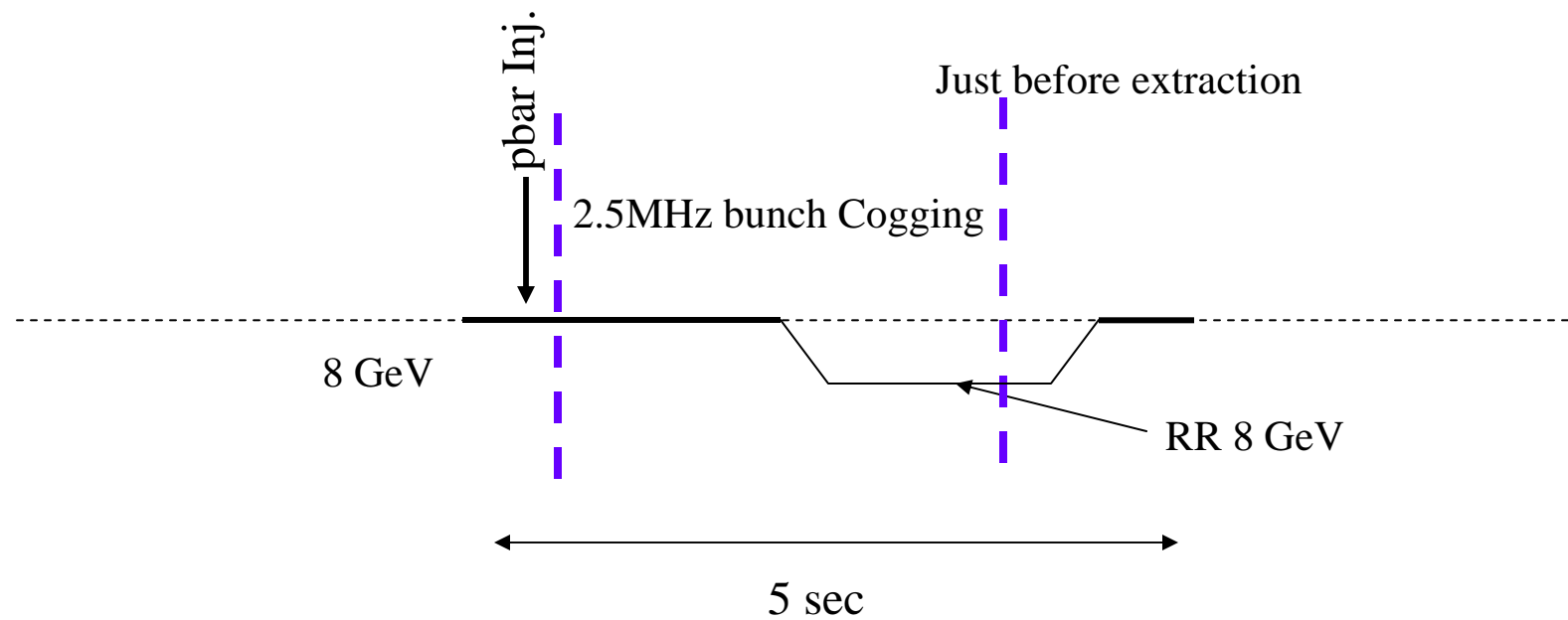


--- Need SBD at these points in the cycle



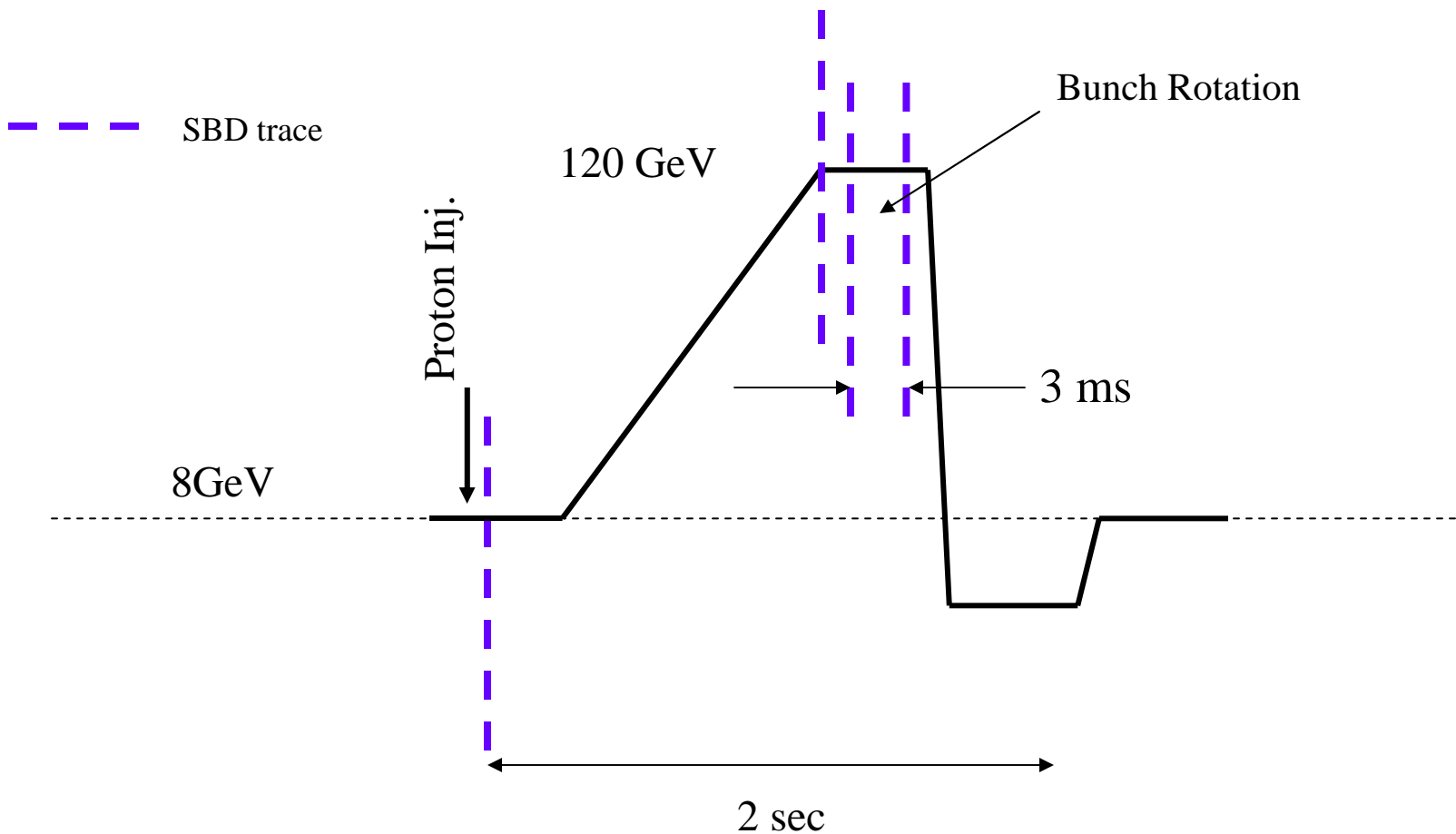
MI cycle: Pbars to RR

--- SBD trace





MI cycle: Protons for Pbar Stacking and NuMI or SY120 experiments





MI SBD Specifications and Requirements



- **Collider Operation:**

- **RMS Bunch length measurements:** 0.4 – 100 nsec with an accuracy of $\pm 10\%$
- Longitudinal Emittance (with an error $< \pm 20\%$. Use measured V_{rf} and bunch length):

Measure up to 5 different timings in the cycle for collider operation both for protons and pbars and, be able to store in SDA

Pbars:

a) On pbar cycles, we need emittance of the beam in 2.5 MHz buckets at injection and with 2.5 MHz pbar acceleration scheme in use, we need emittance of the beam in 2.5MHz buckets at 8 and 27 GeV.

b) During 53MHz acceleration, we need longitudinal emittance measurements at the beginning and at up to 3 different points at 150 GeV for the present mode of operation.

Protons:

Be able to measure long. emittance at 8 GeV, and at four different points up the ramp.

- **Bunch Intensity (better than 2% with respect to the DCCT measurements):**
 - (a) for 53MHz bunches on proton cycles
 - (b) for pbars in 2.5MHz and 53MHz buckets on the pbar cycles.
 - (c) Be able to store in SDA.
- **TV Display of Raw data for protons and pbars (just like now or with improved display) and web-display for the individual to monitor from their offices.**



MI SBD Specifications and Requirements (cont.)

- Pbar stacking, Beam to NuMI and SY120 cycles (mixed mode and unmixed mode operation)
 - **RMS Bunch length measurements:** ≈ 0.4 nsec with an accuracy of $\pm 10\%$.
 - **TV display (torpedo display):** Measured RMS bunch lengths, Bunch intensities and Bunch phases for all 588 bunches and, Coupled bunch mode display.
 - (a) Data should be displayed at 8 GeV injection,
 - (b) at flat top,
 - (c) before proton transfer to pbar target (after bunch rotation) and
 - (d) before proton beam extraction to NuMI target.Note that trigger gap between (c) and (d) is about 2 msec.
These will be used for online beam diagnostic for every cycle of this type.
 - **Datalog**
 - a) batch by batch average RMS bunch lengths,
 - b) batch by batch average bunch intensities, (intensities better than 2% with respect to the DCCT measurements).
 - **TV Display Raw data for protons (just like now or with improved program) and web-display for the individual to monitor from their offices.**
- **Ability for raw data collection for off-line data analysis.**



What problem could arise if the baseline is not corrected properly?

